Analyzing Laser Speckle Pattern Using the Discrete Cosine Transform

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Abstract

The use of Cosine transform to analyze the model-noise pattern alteration with different vibration model applied on multimode fiber optics are studied. It's results compared with the Fourier transform to perform the same analysis using total frequency difference and the computation time, which almost coincide for the both transforms. A discussion for the results and recommendation are introduced.

Keywords: Laser speckle, Model-noise, Discrete Cosine Transform, Fourier Transform, Frequency Domain Analysis.

Introduction

Laser fiber optic applications are vast now days, that range from telecommunication to sensing. The main application for fiber optics is data-transfer, where the laser beams usually used to deliver the data as zero-one signal (i.e. dark-light signal). The single-mode fiber usually used to transfer the data, since this kind of fibers allow only one mode of signal to pass through the fiber, therefore, there will be no broadening or distortion in the signal in the other terminal of the fiber. [1]The other kind of fiber optics(i.e. The multimode fiber optics) are usually used to the other applications. This kind of fiber optics suffers of noises, these noises came from the reality that this kind of fibers let a large number of modes of lights pass through it, which will interfere randomly between them causing broadening and distortion to the passed signal. This distortion is known as model noise or speckles. [2] [3]The interference between the different modes in the multimode fiber optics, depends on many factors that cause changing in the fiber dimensions(i.e. length or radius) or its refraction indices, these factors could be heat, strain, joints (connectors or splices) … [4] [5] The distortion in the received signal will appear as amplitude modulation with a constant pattern unless the fiber influence factors changed, this modulation came from the random interference between the lights modes that pass through the fiber. [6] [7]The model noise or speckles, which represents the output pattern will change if any of the factors that influence on the fiber change. Fourier transform is usually used to analyze the changing in the model noise pattern. In this research the change in the output pattern will be studied, using cosine transform and will compare with Fourier transform analysis.

Fourier Transform produces complex numbers in the frequency domain, therefore, and in order to analyze the frequencies we need to convert frequencies from complex numeric to real numeric by calculating the magnitude of the frequencies. The main disadvantage for this conversion is the relationship between the complex number and the magnitude is non-linear. Using cosine transform instead of Fourier transform will produce real number in the frequency domain instead of complex number, which means there is no need to make any alteration in the frequency domain i.e. the alteration in the frequency domain will be restricted to the change in the noise model pattern.

Methodology

A laser system model constructed in order to produce and analyze the model noise pattern, which consist of Helium-Neon laser source, lens, fiber optics (Panduit 62.5/125 Type OFNR (UL)), and screen as illustrated in figure 1. The noise model pattern changes captured using video camera (Canon, HX1, 30 frame per second) as illustrated in figure 2, after applying different influence factors, in this research we used three different vibration frequencies that rating from low, moderate and fast. The second step is analyzing these patterns using cosine and Fourier transforms.

Results and Discussion

To analyze the changing in the model-noise pattern that accumulated difference for each frame comparing with the next frame had been calculated for each vibration mode, then we apply the Fourier and cosine transforms for the accumulated differences vector. For the Fourier transform we calculate the magnitude value for each value in the frequency domain as illustrated in figure 3. By examining figure 3, we can see that the frequencies that contribute in the construction of the model-nose signal increases with the vibration, to show this relationship we calculate the total summation frequencies for each vibration mode as illustrated in figure 4, in which we can see the effect of increasing the vibration to the frequencies in the frequency domain for either transforms, Fourier or Cosine.

Both transforms visually almost have the same behavior, but since the Fourier transform suffer of complex to magnitude conversing, therefore, it does not represent the alteration in the model-noise pattern precise, in contrast to the Cosine transform where the behavior belongs to the changing in the model-nose pattern.

The computation time is calculated for the model-noise frequency domain analysis, to compare the cost time for the two transforms as illustrated in figure 5, where the Cosine transform has less computation time for low vibration mode and increases with the vibration to exceed the Fourier transform computation time.

Conclusion

Using Cosine transform to analyze the alteration in the model-noise pattern with different vibration models gives results coincide with the results of using Fourier transform, in which the total frequency total difference of the both transforms increase with vibration.

Cosine transform is more accurate than the Fourier transform in describing the alteration in the model-noise pattern with vibration, since Fourier transform suffers from additional error caused by converting the complex frequency values to their magnitude, therefore, we recommend cosine transform to analyze the model-noise pattern alteration instead of Fourier transform.

According to the calculated computational time for both transform, using the Cosine transform dose not differ a lot comparing to the Fourier transform.

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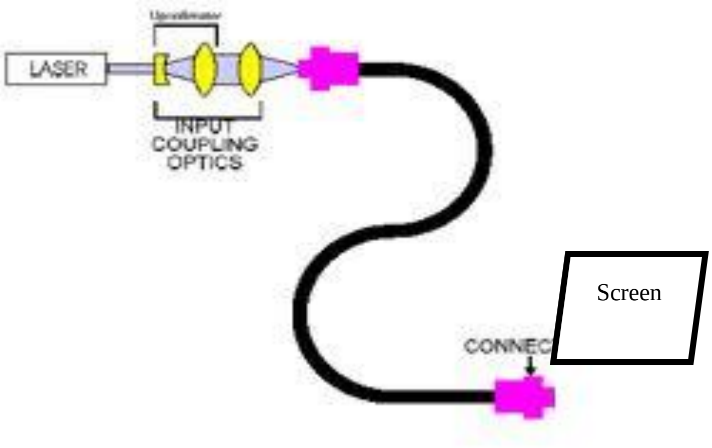


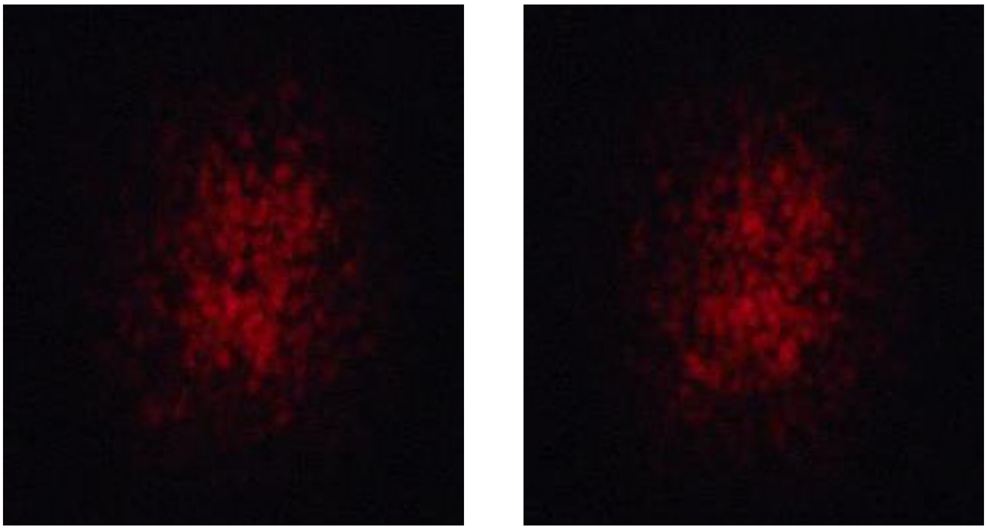


Figure (1) :The components of the Laser system

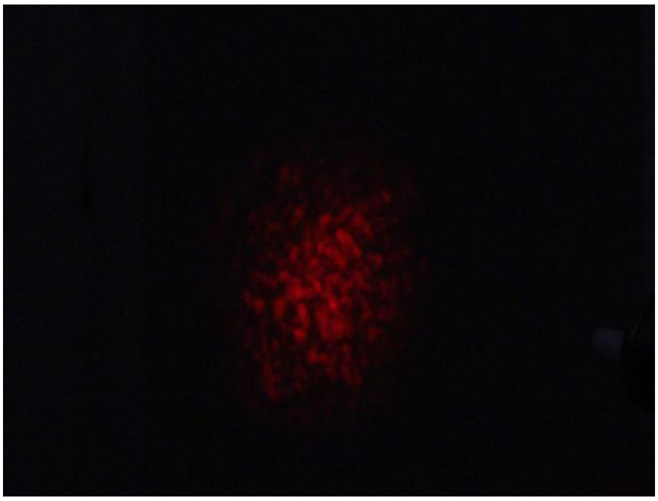
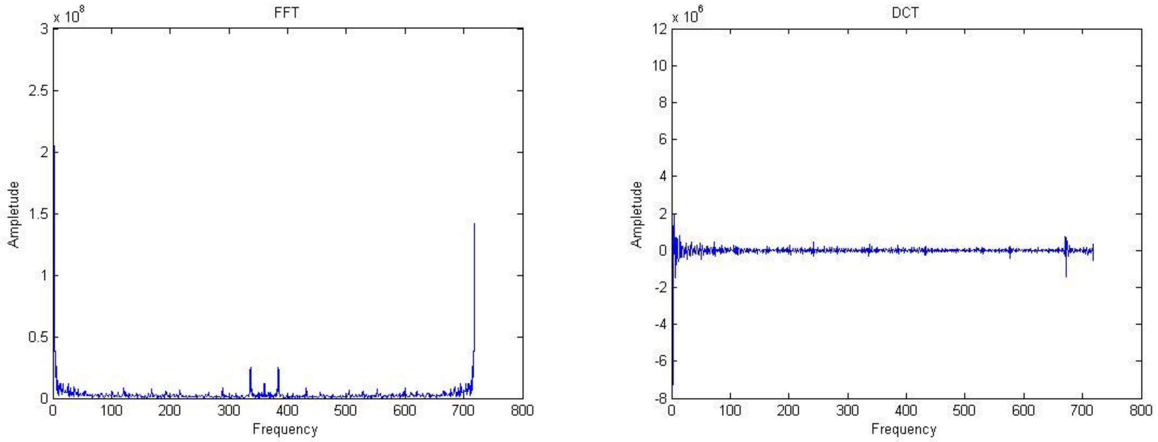
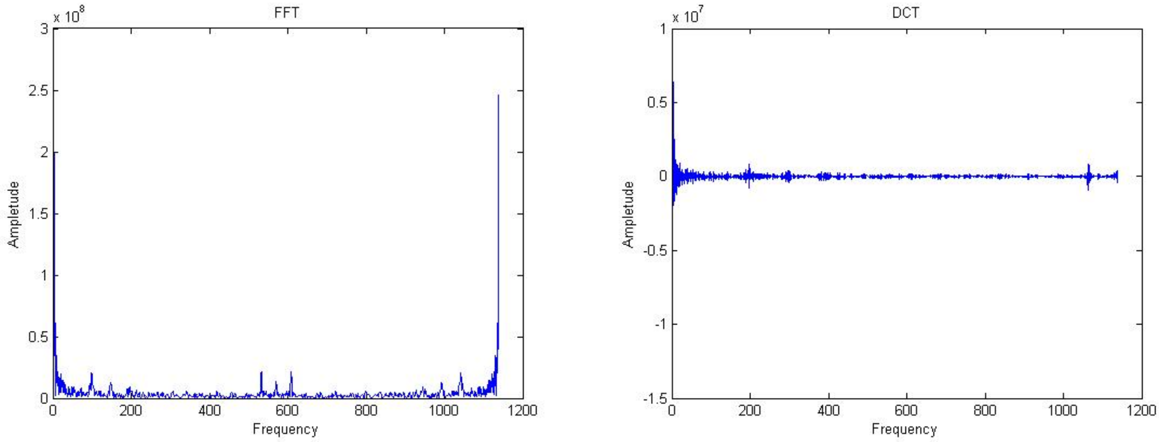


Figure (2): A snap shot of the model-noise pattern

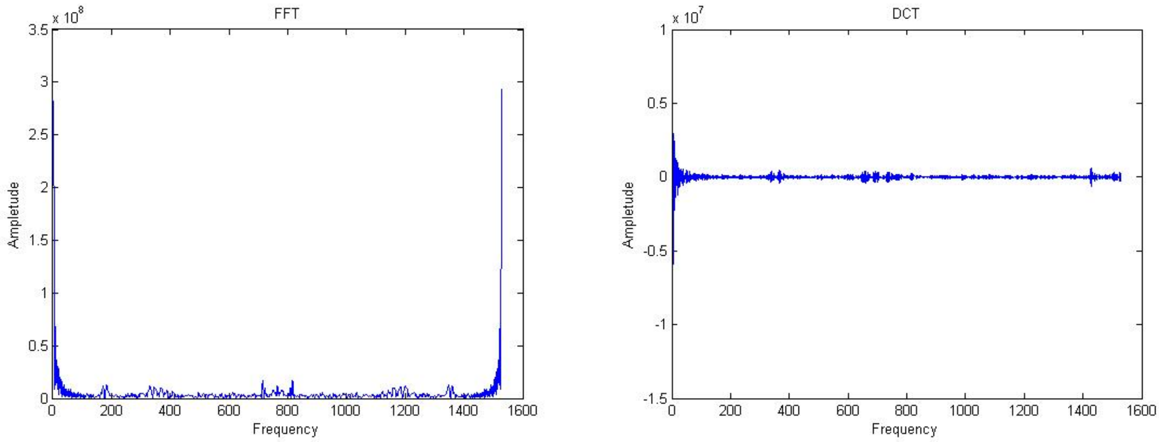
Fourier Analysis **DCT Analysis**



Fast Vibration

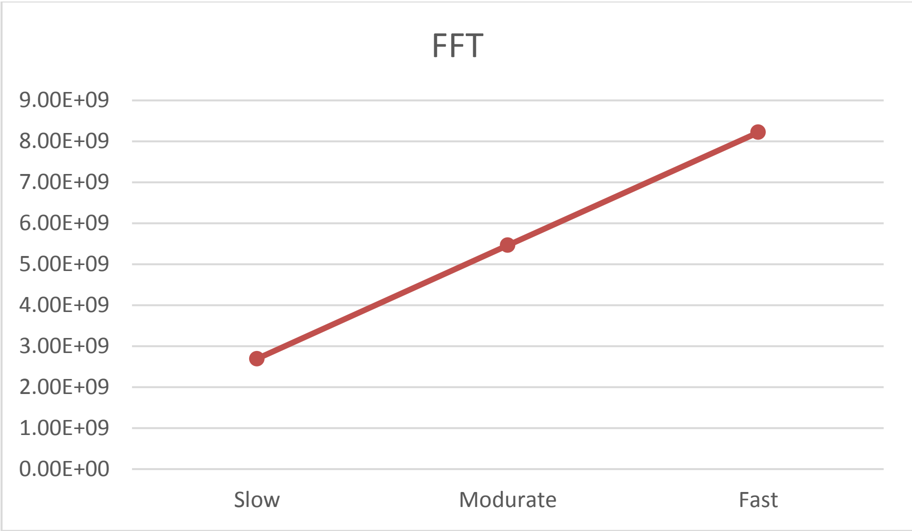


Moderate Vibration



Slow Vibration

Figure (3): Frequency domain using Fourier Transform and Discrete Cosine Transform (DCT) analysis for the model-noise pattern for different vibration modes



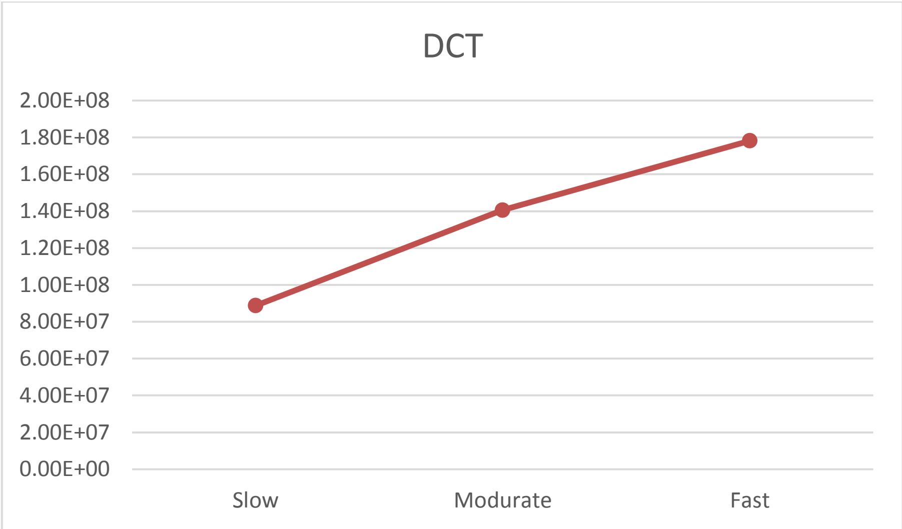
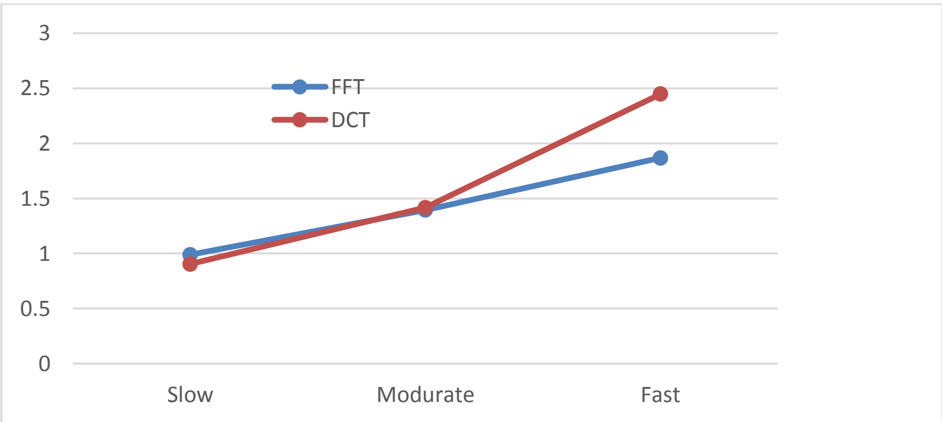


Figure (4) :Total frequency difference for Fourier and Cosine transform



Figure(5): Computation time for Fourier and Cosine transforms for different vibration models